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Cultivations with Modern Tractor Implements

J. C. HAWKINS

National Institute of Agricultural Engineering

WHEN thinking about cultivations, it is as well to start by being clear about the way that implements break up soil, because so much of tillage has this as the objective. With the possible exception of power-driven machines like rotary cultivators, it is a matter of using tools to press on clods while they are supported by the surrounding soil. If the clods are weak and the bulk of the soil is relatively strong, the clods will be crushed: if the clods are strong while the surrounding soil is weak, they will be pushed aside intact.

This squeezing of clods between implement and soil can be likened to the action of a pair of nut crackers with one steel jaw and one lined with stiff putty. If they were used to crack something like a walnut it would just be pushed into the putty; if used on an eggshell, it would be crushed quite easily and the putty would hardly be marked.

Importance of Weathering

Effective soil breakdown, then, depends on arranging for the clods to be as weak as possible while the bulk of the soil is firm. This is a situation that can be brought about only by weathering. The effects of frost are obvious and well known, but alternate wetting and drying is probably much more important. Both lead to fractures and planes of weakness in clods, and at the same time cause the bulk of the soil to settle and so gain in strength.

It may be possible to help weathering by the right primary cultivation, but the production of a tilth today is still a matter of completing something started by the weather, just as it was with primitive man. Claims that modern tractor implements use entirely new principles to break down soil cannot be justified unless the earthworking parts are power-driven. Almost certainly there can be no real progress in soil cultivation until a mechanism is found that will produce any desired tilth regardless of the previous weather conditions and the state of the soil at the time.

EFFECTS OF TINES, ROLLS AND DISCS

Implements do, however, differ in their effectiveness in breaking clods, depending on the direction in which they apply a load, the area over which they apply it and the speed at which it is applied. The tines of cultivators and harrows apply a load to clods more or less horizontally, a direction in which the bulk of the soil can offer the least resistance. The most consistent effect of these implements is, therefore, to bring about consolidation by re-arranging the soil aggregates so that they pack together more closely.

Rolls apply their load to clods almost vertically, a direction in which the soil can provide the greatest resistance, and so they are often more efficient as clod breakers. Unless a roll is very much heavier than those in common use, it will produce relatively little consolidation below the top inch or two because its weight is spread over a substantial area. Discs apply their load to clods almost vertically like rolls; but the loading is high because it is applied over a small area. They, therefore, cut through any clods on the line of the disc and break others as they move them sideways by pressing on them horizontally like tines.

ROTARY CULTIVATION

The effect of speed is probably seen most clearly with rotary cultivators. They apply a load to clods vertically, like rolls, and the thin blades give high local loadings like discs, but they do this at a speed of about 11 m.p.h. instead of 3 or 4 m.p.h. Clods struck at this speed can offer a greater resistance because of their inertia and so are broken instead of being moved aside. In addition, others are thrown against the shield round the rotor at much the same speed and so receive blows equivalent to being dropped from a height of about 4 ft on to a hard surface.

The combination of these two processes enables rotary cultivators to break hard clods in a dry period even when the bulk of the soil is loose and, therefore, weak. The tilth that they make, however, will be different from that produced by other implements in that it will usually contain many more fine particles which could be classed as dust.[1] This could be a serious disadvantage from the point of view of the crop, if heavy rain follows, because the water may carry these fine particles downwards until they settle into the smaller spaces in the soil that would be better filled with air or water.

Value of Tilth

Such criticism of the action of rotary cultivators calls for a more precise definition of what is a good tilth or seedbed. It clearly cannot be adequately defined in terms of aggregate sizes: a certain size distribution and arrangement of aggregates that is ideal on one soil may not be on another. It is the properties that tilth confers on the soil that are important and whether it provides an environment that will give plant roots all that they want.

Looked at this way, the definition of an ideal tilth must take account of such properties as nutrient status, water-holding capacity, soil temperature, aeration and the resistance to root penetration. Cultivations can do very little to affect the first of these, but will have a great bearing on the last two—aeration and root penetration. These, then, are the two that should be studied first to find out how important they are in plant growth, and hence how cultivations should be done to provide a tilth which is adequate from these points of view.

AERATION AND ROOT PENETRATION

Aeration is important because it is necessary to provide an easy path for the oxygen for respiration to diffuse to plant roots and soil micro-organisms and for the carbon dioxide to leave them. In considering this aspect of a tilth, drainage must not be forgotten because spaces in the soil that are filled with water cannot provide channels for gas movement. The unknown quantity, however, is the rate of diffusion of gases in and out of the soil that is needed for maximum growth.

On this there is very little information at the moment, although work is going on to determine the oxygen requirement of soil and plant roots[2] and to find a way of measuring the rates of diffusion of gases in soil in the field. Similarly, nobody has so far been able to define, in engineering units, the level at which soil resistance starts to restrict the rate of growth of roots or shoots. Until research has suggested minimum values for these two properties, it is necessary to play safe and to aim at a tilth which errs if anything on the side of providing plenty of air space and a low resistance to roots. When more is known, it may be possible to depart from such thorough cultivation and so save a great deal in the cost of preparing land for a crop.

Organic Matter

Making a good tilth by cultivation is not the whole story in providing the right soil environment for plant roots. The structure must be stable enough to ensure good soil aeration and root movement throughout the life of the crop. This is the most important role of organic matter and there seems little chance that cultivations can do very much to counteract a deficiency.

Loss of Soil Structure

Modern systems of farming usually return less organic matter to the soil than the older ones: it may no longer be profitable to use leys or to make much farmyard manure. Further, tractors and modern machinery make it possible to destroy structure very quickly. Traffic with beet and potato harvesters and with associated transport can do a great deal of harm when the land is wet in the autumn, and it is now possible to do ploughing or cultivations when it would have been a little too wet for horses.

Crops grown on contract are harvested to a date, with less regard to soil conditions than in the past, and new operations like land levelling and irrigation do further damage to structure.

The results of some or all of these practices are becoming obvious on many of the lighter silt soils, especially in the Eastern counties of England,[3] and are beginning to appear elsewhere on the clays. They show up as poor germination and emergence, water standing on well-drained fields, poor growth in patches, if not over the whole field, and difficulty in making a good seedbed unless the weather is ideal.

On the surface, the small clods left when the seedbed was prepared, have probably weathered down and run together to form a cap which could restrict the oxygen supply to germinating seeds and seedlings—stages in a plant's life when it is particularly sensitive to a shortage. Deeper, the soil has settled down so solidly that it is practically impermeable to water, contains no roots or earthworms and by its colour is short of oxygen.

REDUCTION IN PLOUGHING DEPTH

In really serious cases of loss of structure, there may be no alternative but to modify the farming system to provide more organic matter, even at the expense of lower returns per acre. If the situation is less serious, changes in cultivations may suffice, particularly a reduction in the depth of ploughing.

Where organic matter is limited, great harm has been done by deep ploughing. There is much land which once contained sufficient organic matter per acre to preserve good structure in the top six inches or so, when that was the depth of horse ploughing. Tractor ploughing to greater depths has diluted this with soil from below, which has been practically devoid of humus, with the result that the organic matter content is now so low that it cannot maintain a stable structure. It seems logical on such soils to plan ploughing and cultivations to keep the available organic material near the surface where it can do most good and where its absence will be felt most strongly in the early stages of the crop.

This is particularly relevant as recent comprehensive experiments on deep ploughing have shown no marked or consistent increases in yield.[4] Any deeper cultivation required, and there may well be some, can be done by subsoiling. Even this operation should not be more frequent than necessary because, at every passage of a tine, some soil is brought to the surface from the level at which the tip is running.[5]

Very frequent subsoiling can produce many of the effects of deep ploughing but the ill-effects will be kept to a minimum if the land is subsoiled when dry, to give the maximum shattering effect, and if the tine and point are as narrow as possible with most of the tine vertical, so that together they bring only the minimum amount of soil from below to the surface.

AVOIDING HIGH SPEEDS

Where there is a danger that the soil organic matter is becoming barely sufficient to maintain a good structure, high speed ploughing and tillage and rotary cultivation should be avoided. These lead to a greater breakdown of soil and to the formation of more fine particles which can be carried downwards by water to fill spaces that should be filled with air or water.

Farmers on such land should aim at being rather over-equipped for

ploughing and cultivation, so that they can go more slowly if necessary, and be more selective about when they go on to the land. In an average year they should plan to be able to restrict ploughing and cultivation to the shorter periods when soil conditions are ideal, and they may even be able to avoid working land that is too wet in a wet year. Naturally the drainage of the land and the surrounding ditches must be in order to provide the best possible chance of having land dry enough for safe cultivation.

Tractor Wheel Effects

With all such precautions and even on land that is not short of organic matter, tractors are suspected of bringing soil problems that were not encountered with horses. In particular, the modern heavily ballasted pneumatic-tyred tractors are often suspected of consolidating the soil to an extent that prevents the free movement of air and water, and even restricts the growth of plant roots. There seems, however, to be insufficient evidence of true compaction by tractors to support this.

Research in civil engineering has shown that two soil properties are important for effective consolidation: particle size and moisture content. Although the correct moisture content often occurs when the land is in good condition for cultivation, the necessary range of particle size is usually found only on the gravel soils where compaction by tractors is not considered to be a danger. The trouble is usually suspected on the clay soils and fine silts which have a very narrow range of particle sizes. From this it seems likely that the ill-effects of tractor wheels, noticed by farmers, are not due to soil compaction in the strict engineering sense.

SMEARING ON THE SURFACE

The small amount of work that has been done in Britain on the subject suggests that the damage comes instead from a surface smearing and puddling rather than from consolidation in depth. Under the wheels the structure is probably completely destroyed in a skin, perhaps no more than an inch thick, and so forms an impermeable barrier to the free movement of water and air. If this is so, the most serious damage will be by rubber-tyred tractors when ploughing with one wheel in the furrow rather than during cultivation with an implement at the rear that will be taking out the wheel marks.

Any smeared or puddled layer in the furrow bottom is covered by the furrow slice, it is not affected by frost and, unless deliberately destroyed, will remain and grow from year to year until an effective pan has been formed. The restriction on root run brought about in this way will, as with any other type of pan, show up as a reduction in yield, particularly in a dry season. The most obvious way to avoid the risk of forming such a pan is to plough with a crawler tractor or keep both rear wheels on the land, but this is rarely possible or convenient.

The alternative is to subsoil either with a tine mounted behind the tractor wheel or each plough body, so that it runs 3 or 4 inches below the furrow bottom, or as a separate operation. There should be no need for the deep subsoiling that so many farmers consider to be necessary to cure this trouble.

The Future

The plough has long been the basic tillage implement because its weed-killing powers are superior to those of discs or tines in the British climate. This weed control comes from its burying action and it will usually save the cost of some subsequent weed control measures if care is taken in ploughing to see that everything on the surface is properly covered.

The alternative of an increased use of sprays to kill weeds and the adoption of some other implement in place of the plough will probably be more expensive for some time to come. It seems likely, however, that weed killing or even the destruction of a ley may eventually become a matter of choosing the right spray. It will then be necessary to make an entirely new and fundamental approach to cultivation to see if there are not more reliable ways of providing seedbeds, with all the properties that plants need very much more quickly and cheaply than at present.

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Series of Experiments

D. A. Boyd

Rothamsted Experimental Station, Harpenden

The value of planning field experiments as a series to ensure that in spite of the differences between farms and seasons, the experimental results give information over the whole range of circumstances to which they are to be applied, has recently become more widely accepted.

However, many statistical textbooks on the design and analysis of individual experiments devote little or no attention to the problems which arise in planning series of experiments. This is not because decisions on the amount and efficiency of experimentation are of less importance than choice of design but because they are very much more difficult to formulate, and because many of the factors to be considered are peculiar to the particular field of study. This article deals with some general points which have arisen in the course of the design and analysis of series of experiments.

National and Local Series

The results of recent local and national series of experiments have emphasized the gain in efficiency when resources are pooled for a joint attack on a problem. Apart from observation studies and diagnostic trials designed to answer an advisory problem on a particular farm, isolated trials are usually of little value by themselves, as the results cannot with any certainty be applied to other farms or other seasons; this information can only be obtained from a series of experiments.

The Average Result

Faced by the great variation in soils and farming types within a region or even a county, it is natural for the adviser to mistrust the average result from a "national" series of experiments. To answer any general problem, however, it seems sensible to spread the experimental work widely, so as to allow reliable general conclusions to be drawn as soon as possible; the variation from site to site will show whether it is likely to be worth while exploring local differences more fully.

For those aspects of husbandry in which practice is changing rapidly, it may be impracticable to look for anything more detailed than the broadest regional differences between treatment effects. Moreover, those subjects which have been investigated fairly intensively, for example, crop varieties and manuring, have in fact shown little clear evidence of regional variation as such, other than the broad distinction between upland and lowland, or between high-rainfall districts and the rest of the country. Most of the variation has been much more local in character.

Effect of External Factors

A series of experiments should not merely provide information on the average effect of the treatments and their variation from site to site; it should also be able to show how the treatments are affected by external factors such as soil nutrient status, previous crop, farming type and so on. The extent to which this is possible depends very much on how the series is planned.

CHOICE OF SITE

In many "national" series of experiments the choice of site has been left entirely to the discretion of the local worker, but it is likely to be much more efficient if some, at least, of the major factors can be taken into account in choosing the sites. Otherwise it might be found, for example, that by chance most of the sites were on dairy farms in one year and on arable farms in another, so that the "effect" of farming type would be mixed up with seasonal differences.

The potato manurial experiments by the N.A.A.S. Soil Chemists from 1955 to 1959 are an example of a "national" series which was also well planned. Here the choice of site was confined to certain soil series, or, where mapping has yet to be done, to groups of soil series associated with geological series. Although it is not yet clear how much of the local differences can be attributed to soil series and how much to soil texture, differences from soil to soil in the optimal levels of fertilizer nutrients have been large.

IMPORTANCE OF FIELD RECORDS

Analysis of recent series of experiments has drawn attention to the importance of full and uniform field records for every experimental site. In cereal experiments, for example, varietal comparisons on the effect of nitrogen or seed rate are much affected by pest and disease attack, the extent of lodging and by manurial residues from previous crops; without full information on factors of this kind the reasons for variations in treatment effects cannot be accounted for.

Subject to any restrictions on the major external factors, ideally the sites should be chosen at random, but this is never likely to be practicable, and it is sufficient to ensure that they are reasonably representative of those farms to which the information is likely to be applied. Generally speaking, experiments tend to be laid out on better-than-average farms, because advisory and research workers are in close contact with such farms, and because the farmers themselves are interested in experimental work and can provide the facilities required.

If the farmers are also those most likely to be influenced by advice, such a bias in selection may not be wholly a bad thing, but if experiments are confined to the farms of a few leading farmers, there is a risk that the results may be inapplicable to the majority of farms in the county or region. The risk will be accentuated if sites for experiments are found on the same farms year after year, as in some N.A.A.S./N.I.A.B. variety trials in recent years.

Number of Centres and Years

Detailed recommendations cannot be given on the number of sites likely to be required for a series, because they will vary according to the subject to be investigated and the resources available. To give some indication of the possible range, a small local series can consist of as few as 2 sites a year for 3 years; even for a national average, about 15 sites in each of 3 years have been estimated to give information accurate enough for cereal variety comparisons. By contrast, the series of potato experiments, already referred to, had about 150 centres spread over 5 years.

Generally speaking, the adviser must make his recommendations on the basis of an average season, except where specific advice can be given in advance each season, as with many spraying operations against pest and disease, and so it has become fairly general practice for recommendations to be based on means of at least three years. If the treatments are likely to be much affected by season as, for example, sowing date or nitrogen fertilizer, a minimum of five years may be appropriate. This need not rule out interim reporting of the results or, if necessary, modifications of the original treatments.

Number of Plots per Site

The writer is often asked whether it is more efficient to do many simple experiments or fewer complex ones. In practice, these are rarely practicable alternatives, because decreasing plot numbers per site usually has little effect on the number of sites which can be completed.

As most field experiments on commercial farms are done by teams working from a research or advisory centre, the overheads of travelling time, finding the farmer and preparing the site are large in relation to the time spent per plot, and so the resources will be most efficiently used when the number of plots per centre is just large enough to be done comfortably in a day. Thus, simple experiments cannot necessarily be done in greater numbers than complex ones, unless the team is entirely independent of the farmer in respect of both labour and machinery or the farmer himself is responsible for the work.

Experimental Design

If the questions which the experiments are designed to answer are simple ones, there is every reason for not complicating the issue, but the introduction of additional treatments will often considerably enhance the value of the experiment without substantially increasing the amount of work to be done.

Suppose that several strains of beans which differ appreciably in seed size or habit of growth are to be tested; if their field behaviour is not well known, it may be sensible to test these strains at various seed rates and row widths, to ensure that the varieties can be compared at about the optimal plant population for each variety.

FACTORIAL DESIGNS

Factorial experiments now form a very much larger part of the total number of experiments than they did ten or more years ago. The average effects of treatments which remain reasonably stable over the years are now well known and more detailed knowledge is being sought, such as how one factor varies according to the level of one or more other factors; thus, instead of estimating the average response to each fertilizer nutrient, the Soil Chemist wants to know what is the combined optimal dressing of the three major nutrients NPK applied together.

For the complex factorial design required to answer this type of question, such as the well-known 3^3 design on 27 plots, the total number of treatments combinations is usually too large to allow replication. Consequently the comparison of individual treatment combinations in a single experiment is of very low accuracy and, often, only the mean response to each nutrient will bear independent examination. To form any useful impression of the optimum requirement of all three nutrients the replications provided by a series of experiments on similar sites is needed.

INTERACTIONS

In the customary approach to factorial experiments, high-order interactions are confounded with blocks to reduce block size or are used to provide estimates of error. In the past, statisticians have tended to play down the importance of interactions, partly because they interfere with the convenient property of additivity of the main effects, but also because, when compared over miscellaneous soils and farming types, their occurrence seemed largely a matter of chance.

Improvements in the quality of experiments and changes in the treatments themselves have created conditions much more favourable to a study of interactions than formerly. Recently it has been shown that, when compared within soil series or groups of series, and in relation to the nutrient status of the soil, the two-factor interactions between plant nutrients are usually quite consistent.

Experiments with fertilizers and FYM on potatoes at Rothamsted and elsewhere (Boyd 1959[1]) showed that even three-factor interactions of FYM and fertilizer nutrients were large enough to be of considerable practical importance. Failure to take account of interactions has in fact led to under-estimation of the effective N and K content of FYM and to a good deal of incorrect advice being given on the P requirements of potatoes in recent years. The examples quoted are from manurial experiments, but similar observations might be applied to combinations of many other factors.

Changes in Layout and Technique

As well as changes in the type of information sought in modern field experiments, there have been substantial changes in plot layout and

technique. Cereal experiments, in particular, are very much more accurate than formerly, probably mainly because the combine harvester makes it practicable to lay down experiments with very long narrow plots, but also partly because techniques have generally improved. Also, field conditions may be rather more uniform than formerly as a result of better cultivations, weed control and lime and fertilizer use. However, it seems that techniques could be improved still further, since some N.A.A.S. Regional experiments are consistently more accurate than those in other Regions.

The changed experimental conditions outlined above suggest that modifications may be required in some aspects of experimental design and analysis. In factorial experiments, estimation of high-order interactions and their interpretation is simplified if there is no confounding; confounding has been widely used to take advantage of the supposedly greater accuracy of small blocks, but the plot errors of recent series done in blocks of 20–30 plots have been low enough to throw doubt on the necessity of using small blocks. Other points which merit re-examination include the validity of plot errors estimated from high-order interactions, as in the 3^3 (single replicate) design, as compared with true replication, and the extent to which plot errors vary according to the size of treatment effects.

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Developments in Methods of Handling Manure

C. CULPIN

National Agricultural Advisory Service

ON most British farms, there is no doubt in the farmer's mind about the value of farmyard manure, and since hydraulic tractor loaders and reasonably efficient mechanical manure spreaders are available, it is a fairly simple matter to return it to the land. The increase in use of straw yards, therefore, raises no serious manure handling problem. Indeed, where the yard and parlour system displaces a cowshed, easier handling of manure and more efficient use of the urine are among the important advantages.

In the meantime, developments in mechanization have made it possible for those who use cowsheds to do the daily cleaning out without resort to the usual brush, shovel and barrow. One system uses an electrically-driven endless chain, fitted with paddles which run along the gutters and deliver the manure up a ramp outside the cowshed, on pressing a button.[1] A 2 h.p. motor drives the cleaner. Similar machines are becoming fairly widely used in several foreign countries and cost of the equipment is just over £400 for a 40-cow herd. There are also reciprocating types with paddles which fold back during the reverse stroke, and cable-operated scoops which are used for cleaning out the gutters in piggeries, and occasionally for cleaning out droppings pits in poultry houses.

Handling liquid manure that contains little or no solid matter is no new problem, and since an investigation was carried out by Machinery Advisory Officers of the N.A.A.S. in 1953,[2] it has become much easier, owing to the development of improved trailer-type spreaders, most of which are filled by vacuum pump. It is worth recalling, however, that the analyses of samples carried out at that time by the Regional Soil Chemists, showed that the average fertilizer value of the liquid was a little less than £2 per 1,000 gallons. At this, or lower values, a high expenditure on equipment or labour for spreading can make its use unattractive, compared with buying equivalent artificial fertilizers.

New and more difficult Problems

Some recent changes in systems of keeping cattle, such as the practice of zero grazing and the use of slatted floors, have thrown up new and more difficult manure handling problems, which have to be faced and overcome, whatever the farmer's views on the fertilizing value of the manure. This applies in particular to farmers who are self-feeding silage or "zero grazing". The situation is rather similar in Tasmania, where Chartier[3] argues in favour of making proper arrangements to distribute the liquid manure that comes from cowsheds and piggeries, if only to

avoid an unhygienic nuisance. He estimates that the potential value of the manure from a farm with a 60-cow dairy herd and 60 bacon pigs produced intensively, is as follows:

Soil Nutrients	Manurial Equivalent		Value
	From Cows	From Pigs	
FROM DUNG:	*cwt*	*cwt*	£
N as Sulphate of Ammonia . .	12	23	70
K as Muriate of Potash . . .	6	6	21
P as Superphosphate . . .	10	12	15½
			106½
FROM URINE:			
N as Sulphate of Ammonia . .	12	12	48
K as Muriate of Potash . . .	17	4	37
P as Superphosphate . . .		2	1½
			86½

The total potential value of the manure, on this reckoning, is nearly £200; but it must be remembered that a high proportion of this is in the form of volatile and easily leached nitrogenous compounds such as ammonia, and a considerable proportion of this can easily be lost.

The volume of daily production of liquid, including some washing water, was reckoned at 100–250 gal for the 50-cow dairy herd, and 100–200 gal for 30 bacon pigs. Chartier gives plans and specifications for a simple sump of 1,500-gal capacity, and for a more complex pit of 1,800-gal capacity, together with a 1,500-gal sump. He recommends application rates of 2,500–4,500 gal per acre, depending on the dilution.

The Gülle System

The problem of handling the mixture of dung, urine and some contaminents produced near self-feed silos and in zero-grazing yards, is in some respects akin to that which faces those mountain farmers in Switzerland, Germany and Austria who employ what is known as the "Gülle" system. Articles by Dr. F. Brunner[4] of the Experimental Station at Aulendorf, Wurttenburg, explain how a limited amount of fertilizer is made to yield maximum returns by being applied to the land, used in the crop, eaten and used again two or three times a season. The Gülle farms are often 100 per cent grass and produce mainly hard cheese. The Gülle consists of urine, dung, a little bedding and some water. It is estimated by Brunner that 1 cow equivalent produces annually in dung and urine the equivalent of 1 cwt 42 lb nitrogen, 2 cwt 27 lb potash, 47 lb phosphorus, and 103 lb lime. These estimates are

high, and not all of the nitrogen can be returned without loss to the land.

A common method of distributing the mixture now is to use a simple piston pump which delivers the liquid through irrigation pipes to a rainer or a special manure thrower. Sometimes, a straw chopping device is used in conjunction with it. Similar equipment has now been introduced into England, and Rundle[5] has described how the system can be fitted into British farming practices. On one farm a 3-piston pump first delivers the surface liquid from the manure tank on to a concrete yard to wash down after the 120-cow herd, and later pumps the mixture through an irrigation main to a vector-type rainer.

For washing down, the pump supplies 100-120 g.p.m. at 75 lb per sq. in. pressure, and this enables the job to be completed in 10 minutes each day, compared with 2 hours or more when the yard was swept down by hand. The dunging passages of a pig fattening house are cleaned by a blade on a 2-wheeled tractor, and this manure passes straight to the pit. Details are given of the construction of a collecting pit fitted with a suitable agitator. It is recommended that the capacity should be 1 cu. yd for each cow and for each 5 pigs. A simple, single-stage centrifugal pump can be used where the delivery-head required is not over about 50 lb per sq. in.

CLEANING CONCRETE SURFACES

One of the frequent problems of self-feeding of silage and zero grazing is how best to move semi-solid dung from a concrete surface into a pit where it can be mixed effectively with the urine and with water. An investigation in the U.S.A.[6] has shown that where the manure is to be removed by a jet of water, a solid-spray pattern with a pressure of about 80 lb per sq. in. was the best of the treatments tried. Cleaning was better at 100lb per sq. in., but dilution of the manure tended to be excessive. Where the manure was not allowed to dry out, minor roughness of the concrete surface had little effect on ease of cleaning. It was observed that in many circumstances it may be more practical to scrape solids into an open gutter before washing down.

At present, little is known concerning the best methods of disposing of the manure produced by stock kept on slatted floors, but it is already clear that one possible method is to handle it in liquid form, as in the Gülle system. Where this is attempted, it seems necessary to design the floor beneath the slats so that the manure never dries out. This method has proved very successful where well-designed systems have been used for disposing of the dung and urine from whey-fed pigs.

Liquid Fertilizers

A general review of progress in the application of nitrogenous fertilizers in gaseous and liquid form has been issued by the Working Party on Mechanization of Agriculture of the Economic Commission for Europe.[7]

This report, which was prepared by a Czech rapporteur, shows that the use of anhydrous ammonia is being rapidly expanded in some countries, notably Czechoslovakia, and that development work is in progress in several European countries.

The main advantage of liquid nitrogenous fertilizers is stated to be a lower cost of production per unit of nitrogen, and it is reported that crop responses are at least as good as those obtained with solid fertilizers, provided that appropriate cultural practices and methods of application are used. Disadvantages, which are not emphasized, include the complexity and rather high cost of specialized field machines, and the problems of transport and storage. The report gives information on usage in different countries, and some details of design requirements.

ANHYDROUS AMMONIA AND AQUA AMMONIA

There are many American reports giving details concerning particular aspects of handling anhydrous ammonia and other liquid manures. Hansen [8] discusses the engineering problems generally, and emphasizes the differences between the needs for handling anhydrous ammonia, a highly volatile liquid which develops a pressure of 127 lb/sq. in. at 70°F, and aqua ammonia containing 22 per cent N, which has no vapour pressure at temperatures below 89°F. Hedman and Turner [9] discuss some of the problems of securing accurate metering of anhydrous ammonia, and describe the equipment developed in the U.S.A. for the purpose.

Handling fertilizer solutions is very much easier than handling anhydrous ammonia, but it should be emphasized that even aqua ammonia at 22 per cent N must be covered by 4 in. of soil when applied. Methods of metering such liquids include:

1. Gravity flow. This has many disadvantages but can be acceptable with good design.
2. Pneumatic—a constant head being produced by an air compressor.
3. Hydraulic—a constant pressure being maintained by pump, and excess returned to the tank.
4. Ground wheel drive to "squeeze" hose-pump.

The last of these methods is fully described and illustrated in a U.S.D.A. Bulletin.[10] The hose-pump consists essentially of 1–12 or more plastic-type hoses that are stretched over a 4-roller reel. As the reel turns, the rollers move along the hoses and close them at the points where the rollers are in contact. The hoses are connected to the supply tank, and the liquid contained in them keeps the hose open and full of liquid between the rollers. Thus, as the rollers rotate, columns of liquid are pushed along the hoses and out at the open ends. The discharge rates are very uniform, and the complete hose-pump is sold at prices ranging from about £40 to £80. The U.S.D.A. Bulletin includes a table showing what quantities of mixed fertilizer solutions and nitrogen fertilizer solutions are equivalent to various weights of dry fertilizer of

similar analysis. There can be no doubt that if liquid fertilizers are to be used in Britain, the hose-pump method of application is one that will need to be carefully studied.

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Nutritional Considerations with Self-fed Silage

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IT IS claimed that self-feeding of silage considerably reduces concentrate requirements below the levels of traditional feeding systems, but data obtained by Hodges and O'Connor[13] and by Morgan[16] show that in practice, concentrate savings are often not as great as is popularly believed. Low-quality silage appears to be the main reason for the need to feed large amounts of concentrates. Obviously, successful self-feeding depends chiefly upon the feeding value of the silage. This paper considers recent ideas and experiments that help to define nutritional essentials for successful self-feeding.

Acceptability and Appetite

Crampton[4] proposed that the feeding value of a forage is governed by its ability to meet the energy requirements of the animal, because, relative to protein and mineral content etc, most forages are deficient in energy. Differences between forages in this respect depend upon their relative voluntary consumption or acceptability by the animal.

From experimental evidence Crampton concluded that the acceptability of a forage is "of greater significance in the economics of forage feeding than is either nutrient or useful energy concentration". Thus, based on this premise, a major nutritional problem of self-feeding of silage is the encouragement of maximum intake or appetite—appetite being measured as dry matter intake per unit of body weight.* Blaxter[2] has concluded that appetite in the ruminant is controlled chiefly by the physical effects of gut distension produced by the weight of digesta or "fill" in the digestive tract. Blaxter, Graham and Wainman[1] showed that "fill" is a function of dry matter intake, of rate of passage of the food through the tract, and of the digestibility of the food. Highly digestible foods that have a rapid rate of passage cause less distension than those that pass slowly. Crampton[4] also found an inverse relationship between dry matter consumption and indigestibility.

Two basic principles may now be formulated:

1. Ideally, silage should be produced from young, highly-digestible grass. Such material would stimulate production by encouraging appetite, and by virtue of its concentration of digestible nutrients.
2. Failure to produce young leafy silage, because of failure to control herbage growth successfully, or to provide additional bulk, need not deter a successful self-feeding programme, provided that the "made" silage is sufficiently acceptable to the animal.

* Intake per unit of metabolic body weight (i.e., $W^{\cdot 734}$) is probably a more scientifically correct measure of appetite.

It is necessary to consider (a) those properties of silage that encourage or discourage appetite, (b) the effect of method of ensiling on these properties, and (c) how ensilage compares with other methods of conservation (natural or barn hay drying) with regard to forage consumption and efficiency of utilization.

Importance of Dry Matter Content

A number of experiments have demonstrated differences in dry matter consumption between herbage ensiled immediately after cutting, ensiled after wilting or made into hay either naturally or artificially. Some relevant data showing comparisons of wilted and non-wilted silage are given in Table 1.

Table 1

Relationship of Dry Matter Content of Silage to Dry Matter Intake by Dairy Cows

Author	Crop	Treatment	Percentage Dry Matter	Dry Matter Intake per 100 lb Body L. Wt.
				lb
Moore[15]	Cocksfoot	Unwilted	20·3	1·36
	,,	Wilted	33·1	2·00
Moore[15]	Lucerne	Unwilted	22·1	1·23
	,,	Wilted	27·3	1·94
	,,	Wilted	34·4	2·34
	,,	Half-dry	45·7	2·52
Murdoch[17]	Lucerne/ Cocksfoot	Unwilted	18·7	1·31*
	,,	Wilted	26·5	1·51

* Calculated from Murdoch's data.

These results show advantages of 0·20–1·00 lb of dry matter per 100 lb of body liveweight, in favour of wilted silage. When multiplied up to the liveweights of adult cattle, such differences obviously have an important effect on total nutrient intake.

Dodsworth and Campbell[5] also observed that the rate of gain of fattening cattle rose or fell as the dry matter content of the silage fluctuated. Sykes, Converse and Moore[21] compared wilted silage with hay cut from the same crop, when fed in *ad lib.* amounts to growing heifers in age groups of 8–12 months, 12–18 months, and 18–24 months. Dry matter intakes and average daily liveweight gains for the silage groups were below those of the hay groups, particularly with younger animals. As age increased, differences between feeds decreased. Similarly, Everett *et al.*,[6] fed 3 groups of 8 heifers, averaging 674 lb live weight, on *ad lib.* quantities of lacerated high-moisture silage, wilted silage, or hay. All products were made from the same crop at the same stage of

growth. Dry matter consumption and liveweight gain were inversely related to moisture content. The results are illustrated in Table 2.

Table 2

Effect of Lacerated High-moisture Silage, Wilted Silage and Hay on Dry Matter Intake and Liveweight Gains of Dairy Heifers

Food	Dry Matter Percentage	D.M. Intake per 100 lb Body L.Wt.	Average Daily L.Wt. Gain
		lb	*lb*
Lacerated Silage .	17·9	1·60	0·09
Wilted Silage .	25·0	2·01	1·28
Hay . . .	84·1	2·33	1·69

Experiments with Lactating Cows

Moore[15] quotes results of studies where hay and silage from the same crop have been compared for their effect on dry matter intake and milk yield. In general, appetite for silage dry matter was inferior to that for hay or hay/silage combinations under free choice feeding conditions. Milk yields were similar throughout, but silage dry matter was apparently converted to milk more efficiently than hay dry matter. Hillman and co-workers[11] also found that cows consumed 0·68 lb less dry matter per 100 lb of body live weight when fed wilted lucerne silage compared with lucerne hay from the same crop, cut at the same stage of maturity. Milk yields were the same but the hay group gained 19·4 lb in body weight, whereas the silage group lost 42·4 lb. Gordon *et al.*[8] introduced an additional treatment, and obtained the results summarized in Table 3. Again, all products were prepared from the same crop at the same stage of growth.

Table 3

Comparison of Unwilted Silage, Wilted Silage and Barn-dried Hay for Dairy Cows

Food	Percentage Dry Matter	Total Dry Matter Consumption	Digestibility of Dry Matter	Yield of Fat-Corrected Milk*	Dry Matter Intake per 100 lb F.C.M.
		lb	*per cent*	*lb*	*lb*
Unwilted Silage	20·0	17·8	55	24·6	72·6
Wilted Silage .	44·0	22·2	56	25·9	85·4
Barn-dried Hay .	—	24·6	60	27·1	90·5

* Fat-corrected Milk or 4 per cent fat-corrected milk (F.C.M.) is obtained from the formula F.C.M.=(0.4×milk yield)+(15×fat yield). This formula is used to compare milk yields on an equal energy basis.

The results are self-explanatory, but two points are worth noting:

1. The apparently greater efficiency of utilization of the silage.
2. The higher digestibility of the hay.

Shepherd *et al.*[19] compared wilted silage (34·4 per cent D.M.) with half-dry silage (54·3 per cent D.M.), both silages having been preserved in gas-tight silos. When fed to dairy cows, dry matter consumption was slightly higher (2·52 lb as opposed to 2·34 lb per 100 lb of body live weight) for the half-dry silage. There was little difference in milk production, and it was concluded that little advantage could be gained from wilting beyond about 34·0 per cent dry matter. Another experiment conducted by Hill, Walker and Lundquist[10] showed no essential difference in dry matter consumption of legume/grass silage or hay cut from the same field at the same growth stage. Unfortunately no analytical data were included in this report, but from the average dry matter and average total silage consumption, it seems that the silage used was much drier than that usually self-fed in Britain.

Hay : Silage Ratios

Experimental results imply that some hay should be fed with self-feed silage to increase total forage dry matter intake. Thus in a three-year study, Pratt and Conrad[18] fed balanced groups of dairy cows rations in which a constant proportion of 25 per cent of the total dry matter intake was from concentrates and 75 per cent from forages. In the forage portion 0, 20, 50, 80 and 100 per cent was silage, and the balance hay. Both silage and hay were cut from the same grass/legume sward on the same day. In general, dry matter consumption and yield of 4 per cent fat-corrected milk increased slightly as the proportion of hay increased. Hillman *et al.*[12] conducted a similar experiment, the results of which are presented in Table 4. Lucerne hay and silage from the same crop were fed to balanced groups of dairy cows. No concentrates were fed.

Table 4

Influence of Various Hay : Silage Ratios on Dry Matter Intake and Milk Production of Dairy Cows

Group	% of Total Ration Hay : Silage	Total Dry Matter Intake	Dry Matter Intake per 100 lb Body L.Wt.	Daily Yield of F.C.M.	Liveweight Changes
		lb/day	*lb*	*lb*	*lb*
1	0:100	26·2	2·44	26·6	−58
2	25:75	28·6	2·70	26·1	−20
3	50:50	32·8	2·97	29·1	−5
4	75:25	35·1	2·99	31·0	+51
5	100:0	41·0	3·52	30·7	+23

Milk production, changes in body live weight and dry matter intake followed a similar pattern, with a correlation coefficient of +·572 between dry matter intake and milk production. Milk yield was significantly greater in groups 3, 4, and 5 than in groups 1 and 2. Again, silage dry matter was apparently utilized more efficiently than hay for milk production.

Explaining Differences in Acceptability

No completely satisfactory explanations have so far been given for the lower dry matter intakes on unwilted v. wilted silage, or silage v. hay. Dodsworth and Campbell[5] depressed dry matter intake in sheep by feeding water-supplemented silage, and claimed that water within the food could affect gut distension and hence appetite. Murdoch[17] obtained similar results with dairy cows, but states his experiment was on too small a scale to be completely conclusive.

In contrast, Moore[15] suggested that appetite-depressing effects of silage might be related to the fermentation products of high-moisture silage. He proposed that the effects of characteristics like pH, ammonia-nitrogen, butyric acid etc, on appetite and efficiency of food utilization should be evaluated. To this end, Hillman *et al.*[11] fed balanced groups of cattle on (1) lucerne hay, (2) lucerne hay soaked with water, so that the dry matter content equalled that of silage, (3) lucerne silage and (4) lucerne silage treated with sodium hydroxide to give a pH equal to that of hay. Dry matter consumption was the same for untreated hay and the soaked hay. Further, raising the pH did not affect appetite for the silage. However, cows fed hay ate on average 11·5 lb more total dry matter per day than the cows fed silage. Similarly, Everett[7] failed to influence appetite by adding either hydrochloric or acetic acids to hay to reduce the pH to that of silage, or by adding water to silage to reduce dry matter content. But the addition of ground hay to high-moisture silage (17·9 per cent D.M.) to raise the dry matter content to that of wilted silage (25·0 per cent D.M.) significantly increased both dry matter intake and liveweight gains in dairy heifers.

Possibly both water as such and fermentation characteristics are important with the former operating at higher levels of moisture content. In connection with the latter, the results by Gordon *et al.*[9] may be significant. They studied chemical quality and feeding value of cocksfoot/clover silage made either from chopped or long material in walled clamps, in each of 2 years. Some of the abstracted feeding results are shown in Table 5 (p. 114).

In 1954 the chopped silage had a better fermentation and was richer in lactic acid and lower in volatile bases and butyric acid. In 1955 the fermentation patterns were the same for both silages. The lower consumption of silage dry matter in 1955 compared with 1954 was probably associated with a more fibrous and hence less digestible herbage for that year.

Table 5
Results of Feeding Trials[9]

	1954 Silage		1955 Silage	
	Unchopped	Chopped	Unchopped	Chopped
Average F.C.M. lb/cow/day	30·7[a]	33·5[a]	21·5	21·3
% Decline in yield in 30 days	9·5	2·3	14·2	12·0
Feed Dry Matter Consumption (lb)				
Total (Silage	21·9	24·4	16·4	16·1
(Concentrates	7·3	7·3	5·1	5·0
per 100 lb Body (Silage	1·84[b]	2·01[b]	1·75	1·71
L. Wt. (Concentrates	0·61	0·60	0·54	0·53
Total	2·45	2·61	2·29	2·24

a. Difference highly significant. b. Difference approached significance at 5 per cent level (F value obtained =4.46. F value required=4.67).

Unfortunately, little information has been reported about digestibility values or passage rates for silages prepared in various ways. But the higher digestibility of barn dried hay in the experiments of Gordon *et al.*[8] probably explains the greater appetite for, and production from hay. Because silage dry matter is apparently converted to milk more efficiently than hay, further research on the relationship between the various partitioned losses of ensilage, fermentation type, digestibility and appetite, would be desirable. The quantitative significance of digestibility is shown by the following. Blaxter *et al.*[3] found that voluntary intake of dry fodders (45 per cent to 74 per cent digestibility) by sheep, increased as digestibility increased, resulting in even greater voluntary intakes of digestible energy. Thus an increase from 50–55 per cent in digestibility increased energy digested by 32 per cent and the digested energy available above maintenance by 94 per cent. Similarly, with dairy cows, Stone *et al.*[21] found advantages of 39 per cent in hay consumption and 82 per cent in daily digestible dry matter intake, for early, compared with late cut hay. As digestibility fell with advancing maturity from 67·2 to 51·7 per cent, voluntary hay intake fell from 2·72 lb to 1·95 lb per 100 lb of body live weight.

Summary

It is axiomatic for successful self-feeding that farms adopting the system be able to produce sufficient silage. From the limited data currently available it seems that at least 100 lb of silage per cow per day are required, but perhaps a more logical aim would be around 2·5 lb of dry matter per 100 lb live weight per day. Under intensively stocked conditions and on smaller farms some difficulty might be encountered in securing the high yields of dry matter required. On the other hand, it appears from the review by Holmes and Aldrich[14] that production of

such levels is largely a function of nitrogen fertilization—a factor that will help to secure higher yields of immature, highly digestible material.

Given herbage that is very digestible, it is important to secure silage of high dry-matter content. It is still not clear whether dry matter *per se*, or the better fermentation usually obtained when dry material is ensiled, is the more important factor. However, successful ensiling of immature wet material is difficult, and the practice of wilting and chopping as the best means of securing good fermentation is strongly recommended. In the event of more mature silage being produced, either by accident or design, it is still important to ensure a satisfactory fermentation as characterized by high lactic acid and low volatile acid and base contents.

Finally, to stimulate maximum appetite for low-cost forages, and to obtain good conversion rates, it seems desirable to feed a modicum of hay made by the best methods available together with *ad lib.* silage.

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Phytotoxicity of Insecticides

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THE DANGER of phytotoxic damage to the host plant has always been present in the use of insecticides, and before a new compound comes on to the market, the manufacturer has to give most careful consideration to the phytotoxic hazard involved. When damage caused by a particular compound is pronounced:

> either, (1) the compound is abandoned;
> or, (2) its use is confined to a restricted period of plant growth;
> or, (3) its use is suggested only on certain host plants, that do not suffer damage.

As regards Group 1, many chemicals have been found that would make good insecticides but are too phytotoxic to use on growing plants; these have usually been abandoned and have never come on the market.

Examples of Groups 2 and 3

As regards Group 2—the compounds that can be used only in a restricted season of growth—examples are the tar oil washes and DNOC, used to kill the eggs of aphids and other insects on fruit trees during the dormant period. Tar oils are still used to some extent, but DNOC has largely been abandoned as a winter wash although work is in progress at East Malling Research Station, in which DNOC and other insecticides of the normal spray programme are being re-examined to determine their effect on the predators of the fruit tree red spider mite, which contribute to the natural control of this pest.

Another example that may be considered in Group 2 is sodium dimethyl dithiocarbamate (metham-sodium), a soil sterilant for horticultural crops. In many trials this proved to be too phytotoxic when used according to the distributor's directions, and revised directions have now been issued. It is interesting that the residual effect of this chemical varies in different types and conditions of soils and also between crop plant varieties, and the reasons for this are not yet fully understood.

There are, of course, many examples of Group 3—chemicals that can be used on certain host plants only. Azobenzene smokes, which are very effective against glasshouse red spider mite, cannot be used to control this pest on cucumbers. There are also many examples of differences in susceptibility of varieties within one species—for example, "sulphur-shy" apples and gooseberries; copper-sensitive varieties of apples and other plants.

The Search for New Insecticides

With systemic insecticides the problem of phytotoxicity may be even more acute, for in this instance the chemical is brought into intimate contact with the cell components of the host plant. Where the formulation includes surface-active agents and hygroscopic substances, the amounts of a chemical reaching the host cell may be quite large.

Generally speaking, insecticides are less toxic to the host plant than fungicides, since an insect is further divorced in its metabolism from a higher plant than a fungus, and consequently a specific enzyme complex of the insect's metabolism may often be upset by an insecticide without the host plant being seriously affected. This is true for organo-phosphorus compounds, which inhibit insect cholinesterase, but also have some slight effect on plant esterases. By contrast, the organo-mercurial *fungicides*, which are active against a wide range of enzymes containing sulphydryl groups, often cause phytotoxic damage because such enzymes are present in both host and parasite.

It is widely accepted that the search for new insecticides is largely an empirical process and this is supported by what is known of the discovery of a number of important insecticides. Indeed, it applies also to other chemicals with biological activity. For example, the sulphonamides had been in clinical use for six years before an explanation of their mode of action was forthcoming. It is impossible to suggest that the original workers were looking for a compound with a specific mode of action, though at a later stage, planned developments towards finding related compounds with less toxic hazards to the patient became possible.

CURRENT APPROACH

With the gradual increase in knowledge, there is ample evidence to suggest that the current approach in the search for new toxic chemicals with specific activity is becoming far more rational. This is particularly true of research in the Universities and Research Institutes and is well illustrated by developments in the fields of both systemic insecticides and fungicides.

Professor Wigglesworth's unit at Cambridge is concerned with studies in insect physiology. During the course of his work, Dr. David examined the insecticidal activity of a number of inhibitors of the Krebs tricarboxylic acid cycle. Amongst these was sodium fluoroacetate which occurs naturally in the South African plant *Dichapetalum cymosum*. Because of this, it seemed to Dr. David that it might well be tolerated by other plants. This has proved to be so and in sodium fluoroacetate, and fluoroacetamide, we have effective systemic insecticides which cause little damage to the host plant. Professor Wigglesworth's present work on the "juvenile hormone" as a potential insecticide is a further example of the exploitation of a unique aspect of insect physiology.

ANTAGONISTIC SUBSTANCES

Along similar lines, Professor Wain's unit, at Wye, is looking for systemic fungicides. They have extracted what have been termed "antagonistic substances" from broad beans; that is, compounds produced by a higher plant during growth which are antagonistic to micro-organisms and which it is hoped will be identified and subsequently synthesized. Since these compounds have been isolated from higher plants it is to be expected that they will be non-phytotoxic.

Workers in both these units have been conscious of the need to search for chemicals with systemic activity which are either present in plants or non-toxic to them. They have concentrated their research on specific toxicity. Another example of a chemical developed by the same kind of reasoning is the systemic fungicide griseofulvin. This compound is quite specific in interfering with the formation of the chitinous cell wall of the fungus and has no effect on the host plant.

SCREENING AND SYNTHESIS

The approach of the pesticide manufacturers is, of necessity, different. Their policy is to "first find the insecticide" by the "intelligent screening" of large numbers of chemicals. Normally, if a potential insecticide is markedly phytotoxic it will be abandoned or possibly handed over for development as a weedkiller. Occasionally, the chemist may be asked to undertake synthetic work in the hope of reducing the phytotoxicity.

To give an example: diphenylsulphone is a systemic chemical which is phytocidal. Workers at the N.V. Philips-Roxane Chemical Research Laboratory in Holland synthesized 2,4,5,4′-tetrachlorodiphenyl sulphone which has proved to be a very powerful, non-phytotoxic acaricide. It is almost completely insoluble in water, so that in this instance phytotoxicity is avoided because the acaricide does not enter the plant.

COMMERCIAL POLICY

It should be understood that the pesticide manufacturer elects to "screen" chemicals as a matter of commercial policy. He cannot afford to rely entirely on an expensive effort devoted for long periods to fundamental research which may have no immediate commercial application; but in one respect he is in a stronger position than the research worker at a University or Research Institute in that he has a vast store of chemicals available for test.

In the case of a large manufacturer these will not only be compounds made specially for crop protection outlets, but also chemicals synthesized in the first place as pharmaceuticals, dyestuffs, etc. If an active chemical is new, or it can be shown to have a new use or formulation, then it can be patented and this is a serious consideration in an industry which has to sustain a very high expenditure on research in relation to profits. The manufacturer will also have a strong team of synthetic

chemists and physical chemists concerned with formulation who will assist in the rapid development of a potential pesticide. That this policy is not without its rewards, is shown by the discovery and development of BHC, DDT, 2,4-D, and MCPA.

Physiology of Higher Plants

The development of hormone weedkillers which has occurred in this country and elsewhere during the past fifteen years has contributed a vast amount of information on the physiology of higher plants, much of which has a bearing on phytotoxicity problems met with in the development of systemic insecticides.

The original hormone weedkillers 2,4-D and MCPA show specific toxicity to dicotyledonous plants, inducing abnormal apical growth which is eventually lethal, but they have little effect on monocotyledons. More recently, Professor Wain has discovered the activity of chloromethyl phenoxybutyric acid (MCPB). The toxicity of this compound depends on its beta-oxidation to MCPA within the plant. The enzyme system which mediates this breakdown is present in some dicotyledons and not in others and the immediate development from this has been that MCPB can be used to control broad-leaved weeds in crops such as peas and clover leys.

Both Professor Wain's unit and Professor Blackman's at Oxford are studying the detailed cell physiology of the higher plant with a view to exploiting particular peculiarities of metabolism for control by toxic chemicals. The knowledge of the presence or absence of specific enzyme systems in a host plant is of obvious help to the plant protection chemist in limiting his field of search for systemic insecticides.

Aspects of Research

Other aspects of phytotoxicity which are being studied in this country are:

1. the phytotoxicity of arsenic, copper and mercury sprays to apple trees, which is being studied at East Malling with particular reference to the importance of variety and season, and
2. the chemical nature of the leaf cuticle, which is being studied by Dr. J. T. Martin and his colleagues at Long Ashton Research Station.

Entry of a toxic chemical into a leaf is obviously affected by the nature of the cuticle, and its physical state in the presence of surface-active agents and of lipophilic and hydrophilic groups on the chemical. The surface-active agents may themselves be toxic and experience has shown that non-ionic materials are the safest to use, at least on apples and pears which are the only plants to have been examined in detail so far. There is no direct correlation between wetting power and phytotoxicity, but this may be due to differences in the penetration of different surface-active agents. Where anionic or cationic surface-active agents are used, phytotoxic damage may result from the adsorption of the material on

the leaf surface and the solubility in leaf waxes will also affect phytotoxicity.

In Canada, Dr. Ludwig, working in Dr. Hubert Martin's department, has made a comparative study of fungitoxicity and phytotoxicity in an homologous series of thioureas and has evolved a rapid quantitative test for phytotoxicity. More recently, he has isolated an antifungal substance from barley.

Dr. Ludwig's approach in this work has been similar to that of Professor Wain and also of Professor Virtanen, in Finland, who has isolated a number of antifungal substances from plants. These have been identified as benzoxazolinones, but whilst they have appreciable activity *in vitro*, they have not proved to be potent fungicides in the field. Also at East Malling certain polyphenolic substances have been isolated from apple and pear trees which are inhibitory to *Venturia* spp., the causative agents of apple and pear scab diseases.

Conclusions

Whilst one may criticize the empirical approach of the pesticide manufacturer to the discovery and development of non-phytotoxic systemic insecticides, one must appreciate that there is as yet no sure formula that he can apply to overcome phytotoxicity. Each insecticide carries its own problem of specific, associated phytotoxicity.

It has been suggested that a study of the differences in the reaction of host varieties to a specific insecticide might be a suitable problem for a plant physiologist. It must be stressed that, on the basis of past experience, such an *ad hoc* study, if it were to produce any answer at all, might produce only a specific one and give no information of more general application.

Certainly there is a need for more basic information on cell physiology in both host and parasite before the problems of the phytotoxicity of insecticides can be defined with any precision. This basic information is being accumulated step by step in many fields in directions which research workers themselves feel it is most profitable to explore.

When their efforts have been intentionally directed along specific lines with economic ends—such, for example, as determining the nature of copper toxicity—the results have often proved rather meagre. It may be, therefore, that attempts to find a physiological explanation for a particular difference in varietal reaction would yield less, in the end, than the present lines of research. In the meantime, of course, it is important that experimental work on more empirical lines should go on to find the most suitable formulation, and time and method of application, for particular insecticides to minimize damage to the host plant.

Apple Mildew

H. E. CROXALL

N.A.A.S., West Midland Region

ALTHOUGH apple mildew has been known in Britain for about a hundred years, and has been prevalent in many districts, it is only within the last decade that it has caused serious concern to commercial fruit growers. In the last five or six years serious attacks on Cox's Orange Pippin and Bramley, the principal dessert and culinary varieties respectively, have been reported from all the main fruit-growing districts.

There have been a number of reasons put forward to account for this sudden increase in intensity of the disease. It has been suggested that the replacement of spur pruning by less drastic methods such as the renewal system is partly responsible, in that the newer methods do not cut out so much infected wood. However, the renewal system had been in operation in some orchards for a number of years before there was any noticeable deterioration in the mildew position.

To a considerable extent the rise in mildew is associated with the change from lime sulphur and other sulphur-containing sprays to new materials, particularly captan. Finally, a succession of dry springs as in 1955, 1956, and 1957 may have also tended to favour the disease. Woodward[1] also suggests that mild winters may also lead to a build-up of the disease. The probability is that the recent epidemics are due to a combination of all three factors, climatic, changing spray practice and less drastic pruning.

Life History

A knowledge of the life cycle of the disease is essential for devising successful control measures. As long ago as 1927 Woodward[2] showed that the fungus overwintered in living apple buds, while Petherbridge and Dillon Weston[3] investigated secondary spread.

More recently, Burchill[4] has carried out a detailed investigation of the mode of overwintering of apple mildew. He showed that the bud infection which occurred in early summer was due mainly to the mycelium of the fungus growing down the petiole of infected leaves into the young axillary or terminal bud. Once the mycelium had penetrated between the open bud scales, conidia were formed which further spread the infection within the bud.

Air-borne conidia from other leaves played only a minor part in causing bud infection during early summer. If the fungus invaded the apical meristem the bud was killed. Otherwise the fungus was confined to the inner tissues of the bud during winter but as soon as growth started in spring it spread to the outer tissues so that leaves emerged covered by mycelium.

SUSCEPTIBLE PERIOD

Axillary buds were vulnerable to infection from the time they were first seen for a period of three to four weeks until the scales were tightly closed. Thus, during the period of shoot growth successive buds each pass through a susceptible period. Terminal buds were liable to become infected at any time during and just after the shoot extension period.

Once a terminal bud was infected all subsequent leaves on the shoot were also infected. Heavily attacked buds died by the end of summer. Lightly attacked buds survived the winter to produce infected shoots the following spring. If buds were infected late in the season they showed no external sign of mildew until the following year. Axillary fruit buds behaved in the same way as axillary vegetative buds and occasional terminal fruit buds were susceptible late in the growing season. Fruit buds formed on dwarf shoots were susceptible during May and early June.

This work helps to throw light on the variable and often disappointing results obtained from attempts to control mildew by cutting out infection during winter pruning. The obviously mildewed shoots are dead and thus of no importance in carrying over the disease until the following spring. On the other hand late infections which are the most important source of the disease the following spring are difficult or impossible to detect.

Burchill observed that 38 per cent of apparently healthy shoots produced mildew the following spring. He thought that the slightly infected terminal buds were the most important source of inoculum in the spring as infected axillary buds produced only a few distorted leaves. He did not comment on the importance of infected blossom buds providing inoculum for spread as well as being the direct cause of loss of fruit.

Control by Pruning

Theoretically, if all infected buds could be removed before infection starts it would be possible to control the disease. In practice this is impossible, especially as many of the infected shoots are not visible until growth is renewed in spring. It would appear therefore that removal of infected shoots and fruit spurs is best done immediately after pink bud stage when infection on fruit spurs and most terminal shoots is easily visible and infection of new buds has scarcely had time to begin.

Whether the labour and time involved will produce an economic return in increased crop in failure years can only be decided by experiments under British conditions. Burchill has suggested that removal of terminal buds in winter pruning might also be advantageous. In commercial orchards in the West Midlands a reduction in shoot infection has been noted in an area where "tipping" of leaders has been practised.

Loss due to Mildew

It has long been known that lime sulphur is effective in controlling apple mildew. This was first reported by Bedford and Pickering[5] in 1908 and confirmed by M. H. Moore[6] and Marsh.[7] Unfortunately, lime sulphur is toxic to some varieties, among them the popular Cox's Orange Pippin, and can cause serious reduction in crop. Therefore there has been a search for less harmful fungicides to use on apples mainly for scab control.

Of the various organic compounds introduced, captan (N-trichloromethylthio-tetrahydrophthalimide) proved to be the most popular in that it gave a good control of scab and on Cox produced higher yields of high-quality fruit with a good "finish". This material has no effect on mildew, and its use allowed this disease to increase, as found in spraying trials, for example, by Byrde and his co-workers.[8]

There is little information on the losses which apple mildew may cause. This loss has two components: the direct loss of fruit from infected fruit trusses and the loss of tree growth due to infection of shoots. A spraying trial on the variety Lane's Prince Albert which is susceptible to mildew and also sulphur shy, started in 1957 on five-year-old trees at Luddington Experimental Horticulture Station, gives some indication of the losses which may be experienced.[9, 10, 11]

In 1957 there was a uniform infection of only 4–5 blossom trusses per tree. This had risen in 1959 to 4·9 per cent of trusses infected in unsprayed control trees as against 0·25 per cent on sprayed trees. The control trees were smaller as measured by growth, height and spread and in 1959 the yield was only 65 lb per tree compared with 99 lb per tree from the sprayed trees. Although the variety is very mildew sensitive, the level of mildew—5 per cent blossom trusses primarily infected and 60–70 per cent of leaves secondarily infected—is not greater than seen in many commercial orchards. These results show that mildew left uncontrolled for two years may reduce yield by 50 per cent.

Control by Spraying

Where lime sulphur is unacceptable, the choice of spray materials would appear to lie between dispersible or colloidal sulphur materials and karathane, 2,4 dinitro-6-(1-methyl-n-heptyl) phenyl crotonate. There are few strictly comparative results published, but Hey and Hunnam[12] carried out field trials in Kent in 1957 and 1958 using karathane at 1 lb/100 gal, wettable sulphur 2½ lb/100 gal, and mercurite 16 fluid oz/100 gal, each applied seven times between 17th April and 10th July.

The percentage bud infection for each treatment in 1957 was 4·16, 5·41, 5·41 respectively and 8·75 for untreated controls. In 1958 the percentages were 4·75, 11·08, 11·58, and 30·58. These results hardly agree with the statement that mercurite and wettable sulphur were almost as good as karathane. The effect of mildew is cumulative, and

while karathane was successful in preventing any increase from 1957 to 1958, with the two other treatments, the amount of mildew had doubled, though this was a considerably lower rate of increase than with the unsprayed controls.

In the Luddington trial,[11] a mercury compound gave an inferior control to that obtained by karathane and also caused damage to the trees. In Burchill's spraying trials[4] carried out in 1956 and assessed by fruit spur infection in 1957, two applications of karathane 1 lb to 100 gal at pink bud and petal fall gave 2·3 per cent infection compared with 4·6 per cent from 1 per cent lime sulphur applied at the same time. Reports from New Zealand[13] also show that karathane was superior to sulphur in controlling mildew. Thus the available information shows that karathane is a safe and efficient compound for controlling mildew. Unfortunately it is an expensive material, and where infection levels are not high and the varieties not sulphur shy, sulphur compounds may be more economic, especially as they also control apple scab which karathane does not.

Timing of Spray Applications

If karathane is used it is highly desirable to time the applications to get the maximum benefit from the fewest possible applications. Here, reliable information under British conditions is even more scanty. Burchill[4] found that pre-blossom sprays were ineffective in reducing spur infection the following year. This agrees with his information on the life cycle of the fungus in relation to bud development of the tree.

Thus, spraying starting at pink bud stage and continuing at fortnightly intervals until early June should protect most of next year's fruit buds from infection. It will not, however, control late infection of terminal buds. To do this, spraying would probably have to continue until extension growth is completed. In America Groves[14] has found that with spraying at intervals of not less than 14 days during this period the amount of karathane might be reduced to $\frac{1}{2}$ lb per 100 gal. It seems therefore that further experiments are needed in this country on timing and rate of application.

Information is also lacking on the combined effect of spraying and cutting out, though observations made on three commercial Cox orchards in the West Midlands have shown that mildew, expressed as a percentage of fruit trusses infected, may be reduced from over 50 per cent to under 5 per cent by cutting out as much infection as is possible at the pink bud stage, accompanied by spraying four to six times with karathane from pink bud stage at fortnightly intervals.

On the other hand in the Luddington trial,[12] spraying with karathane up to seven times without any cutting out of infection beyond that achieved by routine pruning has given an excellent control of infection. However, in this experiment, it has been the avoidance of a build-up rather than the reduction of an already heavy infection which has been

achieved. The results however do suggest that once mildew has been reduced to about the level of 4–5 per cent infection of fruit spurs, an economic commercial control may be achieved by spraying alone. Only results from further experiments can help to formulate more precise methods of control.

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County Leaflets as an Advisory Tool

L. W. OSBORNE

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GIVING advice to the individual farmer or grower on his holding is the most satisfying and most effective method that advisers have yet developed. We spend most of our time advising in this way. Other methods are however used which can broadly be described as Mass or Group methods and one of the Mass methods, the County Leaflet, is the subject of the present article.

Why did the writer become interested in this kind of approach? It all started in 1955 when studying the pattern of our advisory work in the County. An analysis of the visiting activity of our D.A.Os., all first-rate advisers, showed clearly that in the previous year they had visited a much greater proportion of large than small farms. Furthermore, the average number of visits was greater for the large farms.

Consistency of pattern between our four districts suggested that it was a normal one likely to be repeated in following years. So it has proved, and the five year averages in Table I show little variation from the pattern revealed in 1955.

Table 1

Annual Visiting Activity by D.A.Os. in Cambridgeshire

Mean of 5 years 1955–59

Farm Acreage Group	Percentage of Different Farms Visited	Average Number of Visits per Farm Visited
1–15	2¼	1·8
16–50	13	2·3
51–150	28	2·9
151–300	42	3·1
301–500	49	4·2
501–700	58	4·7
700+	68	6·2

Our research did not make us feel any happier—how could we reach the many farmers (80 per cent in fact) who were not being visited in any one year? There seemed to be two alternatives. We could either increase our visiting activity on the smaller farms or find some other method of getting advice and information to them.

We looked at the first possibility and found that to visit 50 per cent of our farms each year we should need to visit about 1,000 more farms than the 700 we visited in 1955. This would probably double our work load and would add a mere 16,000 acres to the 140,000 acres on which we

already advised. The former would be intolerable and the latter not very rewarding, at least in economic terms.

We therefore decided to try other methods of supplementing our existing advisory activity and we first tried County leaflets. Many problems arose of which the following are a selection:

What topics should we choose?
How should we deal with them?
What kind of presentation would be best?
How should we select the recipients?
What should be our main objectives?
How could we find out whether we were succeeding in our objectives?

We had little experience of this medium and had to work out solutions to the problems as they arose. What follows is therefore rather more an account of "how we did it" than "how to do it". Some of our methods were devised on experience and factual evidence, but much has depended on careful thought upon the general principles involved. There is certainly room for a great deal more factual evidence about the effectiveness of different methods of using this technique of the County leaflet. The same is true of all advisory techniques and the setting up of an Advisory Methods Section of the Agricultural Education Association is a most promising step forward in this field.

Selection of Subject

We have endeavoured to choose our subjects in terms of their economic importance. Thus we have concentrated on subjects like cereal growing, which are worth £5m. a year in Cambridgeshire, and have done nothing whatever on the subject of sheep which bring in a mere £100,000 or so. We also endeavoured to make an assessment of the economic value of the advice that we were to include in the leaflet. Thus in the case of our first project we knew that growing unprofitable varieties of cereals was costing our farmers £$\frac{1}{4}$m. a year.

In selecting our subjects, we have endeavoured to think in terms of those farmers who have problems on their farms but who do not recognize the fact. This involved knowing about problems which existed on farms that we never or rarely saw. Postal surveys provided the answer. Dr. Boyd's article in the Spring 1960 issue of this Journal* has already provided a most valuable contribution on this subject.

Another point that we considered to be important was that in the chosen subjects the advisory solutions should be available and could be stated in simple terms, providing advice for immediate use. The following examples of subjects we have chosen for County leaflets will illustrate this point:

Cereal Varieties and their Top Dressing.
Control of Pests and Diseases such as Carrot Fly, Virus Yellows, Codling Moth, Tomato Diseases.

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* Sampling Surveys in Agriculture. D. A. Boyd, *N.A.A.S. Quart. Rev.* No. 47, **XI**, 108–15.

It would be possible to select subjects for leaflets which would be designed to stimulate thought rather than action. Thus for instance, grassland policy or farm planning are subjects for which principles rather than facts would be set forth, and which would result primarily in a change in the reader's attitude rather than in his actions.

The writer has had no experience of using this kind of leaflet which would be philosophical rather than technical, but undoubtedly it could be used with success. At present the use of leaflets designed to stimulate a fuller awareness among farmers of the value of farm business planning is being considered.

Presentation and Format

Where the main objective is to provide information for those farmers who do not regularly seek it, the information should be presented briefly and all statements should as far as possible be unequivocal. We always endeavour to go straight to the point and to state quite clearly what is the most profitable action.

A uniform design was adopted using coloured paper with a cover page incorporating a standard pictorial design in a contrasting colour.* We considered it very important to devise a simple, attractive "trade mark" so that on the receipt of each leaflet the recipient would be likely to say "Ah, yes, another of those, I must read that. The last one was useful."

Objectives

Our objectives were to get information to farmers who could use it profitably, especially to those who were not being regularly advised and to those who were unaware that their methods were not the most profitable. One could have other objectives, such as reducing the demand for advisory visits on subjects which could be dealt with in a leaflet before the inquiries arose.

It is sometimes suggested that Mass Approach work will result in still more requests for visits. This need not be so and we have plenty of evidence that it does not usually happen. Thus, on one subject we have reduced our requests for visits by 80 per cent as the result of using County Leaflets over a period of years. In another instance a flow of telephone calls seeking advice on an insect pest of wheat was turned off like a tap by sending a leaflet to all farmers in the area.

If the objective is to reduce advisory demands this can undoubtedly be achieved by a careful choice of subject and a well prepared leaflet. If, on the other hand, the objective is to encourage the demand for visits, the same method can be effective.

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* Specimen copies of leaflets used in Cambridgeshire are available on application to the author.

Selecting the Recipients

Circular letters are much cheaper than advisory visits. The "variable costs" of production such as printing and postage amount to about £10 per thousand, assuming postage at 2*d.* per copy.

Wholesale distribution is wasteful of money and manpower, for a few thousand leaflets to be folded and tucked in will represent a severe strain on an already busy clerical staff. Furthermore, sending leaflets to farmers totally disinterested in the subject would only reduce the effectiveness of succeeding leaflets and the second might follow the first into the farmer's fire before it had been read.

There is much to be said for a careful selection of the recipients, but the question is how can this be done? There are three main possibilities.

1. Surveys can be used to select the individual farm or the types of farms where the information in the leaflet is important.
2. N.A.A.S. staff can select the farms to receive the circulars. This method is laborious and not a welcome burden for busy advisers. It also defeats one of the main objectives which is to get information into the hands of those farmers who are not often advised.
3. The best alternative is probably to make full use of the mechanized addressograph system which is already available in some areas. This enables address plates to be coded and tabbed with up to 24 different classifications.

We were fortunate in having such a machine available and over a period of time we classified all our holdings according to farm size and this alone led to considerable economies.

We also included classifications for keepers of cows, pigs, and poultry and for growers of fruit, vegetables, flowers, and glasshouse crops. The classifications can be varied according to local farming interests.

To give some idea of the economies possible by the use of this system we had some 3,600 holdings of over one acre in the county. Of these, 2,500 were under 50 acres and grew only 5 per cent of the county cereal acreage. For £10 we could send a leaflet to the 1,000 farms of over 50 acres which grew 95 per cent of our cereals. It would cost a further £25 and $2\frac{1}{2}$ times as much clerical work to send a leaflet to all the smaller farms.

We now know that large farmers are influenced more by Mass Methods than are small farmers, and that small farmers are much more prone to get information "over the hedge" than are large farmers. Table II illustrates this point, using information from one of our surveys which was designed to evaluate the success of a series of leaflets on choice of cereal varieties.

Thus, although the leaflet appeared to be less effective with the smaller farmers, in fact even with the 10–50-acre group the leaflet was more often quoted than "another farmer" as the most important influence.

The need for economy will usually restrict the number of leaflets sent out, and where it is not possible to send to every small farm, the

Table 2

Influence of Different Media on Choice of Winter Wheat Varieties

(Cambridgeshire 1957)

Farm Acreage Group	Percentage of Farmers quoting as most important Influence:	
	Leaflet	Another Farmer
10–50	26	22
51–150	40	12
151–300	48	10
300+	50	6

evidence from Table 2 suggests that the spread of knowledge "over the hedge" may be considerable.

Not all counties have a full 24-tab addressograph system available and most would probably prefer not to give up control of their own plates. We have not had control of ours for about 8 years and they are now housed by H.M. Stationery Office 80 miles away, yet we get a very efficient service. The centralized system now being planned will bring considerable economies and will also save our staff many hours of effort.

From the writer's own experience a well-classified addressograph system would certainly be put high on the list of essentials for publicity work of this kind, not to mention its usefulness in publicizing local meetings, conferences, and farm walks. It was very depressing to hear on one occasion of a meeting for which over 8,000 invitations were sent and yet only about 20 persons attended!

Justifying the Cost

Leaflets or circulars appear rather costly when dealing with large numbers of farmers, but compared with advisory visits costing about £5 a time they are a very cheap supplement.

Evaluation by surveys can provide evidence strong enough to overcome the most difficult objections which may rely solely upon the need for economy. One fact is worth a thousand opinions! Thus, in one of our experiments involving 118 farmers we were able to show that a leaflet costing less than £5 resulted in changes in farming practice which brought an extra profit of £5,000.

Evaluation

When face to face with his client the adviser can continually evaluate his progress towards his objectives. Each time he makes a suggestion he can observe the farmer's reaction and thereafter he can adjust his approach, taking account of the farmer's particular situation and his

particular attitudes. Furthermore, on a later visit to the farm he can observe the degree of success that he has achieved.

In Mass Approach work this is not possible as every client is advised unseen. This represents a considerable challenge—to make sure that the information given is of general application, is clearly and simply stated, and so forth. There is a further challenge, not unrelated to the first—the question of devising some method of charting progress. If it is remembered that the main objective is often that of influencing farmers who are not regularly visited, information on progress picked up by advisers will not be adequate or representative.

The use of surveys for charting progress is a vital part of any Mass Approach exercise. Not only does it enable faults in communication to be detected and put right, it also provides a satisfying record of successful achievement which serves as a stimulant to further activity by the adviser. Evaluation also shows when the point has been reached where a sufficient degree of success has been achieved and efforts can be directed to new projects.

The County Leaflet is merely one of a number of Mass Approach Methods which can be used as a supplement to advisory visits, which will remain a very important method. The personal contacts involved undoubtedly create an atmosphere in which Mass Approach methods can bear full fruit. Indeed the writer knows that in one county advisory visits are consciously used as an opportunity of drawing attention to the value of the information disseminated in the county by mass methods.

Regional Note

Experiences in the Use of Fluorescent Traced Sprays as an Advisory Tool

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A SHORT article by the writer on the principles of spray tracing has already appeared in this journal.[1] Detailed information on tracing techniques has been published elsewhere;[2] a further article discussed, in some detail, tests of spraying equipment in the field on a variety of crops.[3]

The purpose of this present article is to bring to the notice of advisory officers some of the tests carried out on holdings, where spray tracing has been used as an advisory tool for the purpose of answering growers' or farmers' questions regarding the efficiency of their spraying. No account of these particular tests has appeared elsewhere; they are dealt with briefly in order to cover a number of cases and so point to the value of the techniques to advisers and advised.

Materials and Equipment

Tracing materials used were mainly a suspension tracer, such as Saturn Yellow, particularly where the grower was interested in such suspension sprays as captan and copper oxide. The typical effect as seen by growers during the tests is shown in Plate I. A mixture of a dilute solution of polyvinyl alcohol with a water-soluble fluorescent dye, such as Primuline, was also used where it was desired to detect the distribution of the spray fluid itself when soluble spray materials such as lime sulphur are used and where information on droplet spread and size was of interest. An example of this is shown in Plate II.

The ultra-violet lamp used in the examination of the traced sprays is readily portable and is set up in any darkened shed or room on reaching the holding; a mains supply of electricity is necessary. A simple device for the examination of traced spray deposits in daylight, in the field, has proved satisfactory for basic, but not too detailed, information. An article on its construction and use will be published elsewhere.[4] With this apparatus the adviser can be independent of electricity for making the simpler checks on spraying.

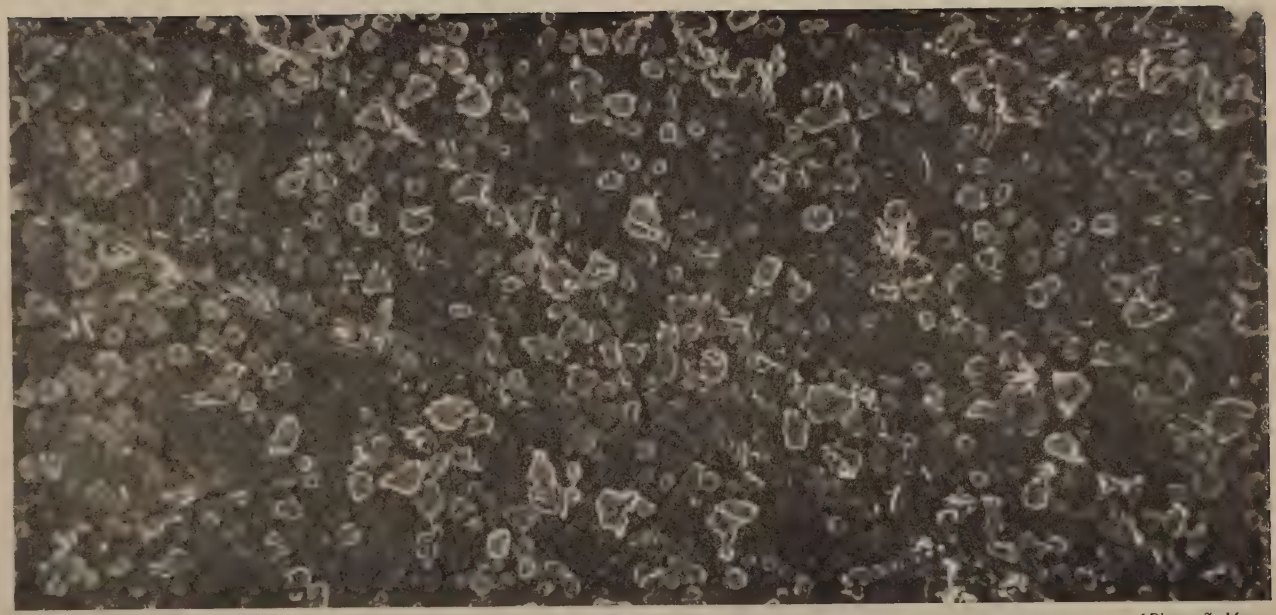
Glasshouse Spraying

Much work has been done on the spraying of glasshouse crops with a variety of equipment. The example given below is typical of the help that can be given.

[*Photo: J. Mayor*

Undersurface of a sprayed cucumber leaf, traced with Saturn Yellow in suspension. Note that spray deposit is almost absent except where the spray has crept round the edge from the upper surface, which had a good cover. (× 5)

PLATE I



[*Photo: J. Mayor*

Apple leaf sprayed with a spray containing polyvinyl alcohol and a water-soluble fluorescent dye (Primuline). This traces the water of the spray and gives information on droplet spread. (× 5)

PLATE II

CONTROL OF MILDEW IN CUCUMBERS

A grower of cucumbers had sprayed with a proven fungicide a number of times at weekly intervals, applying 400–500 gal per acre (g.p.a.). Despite this, his control of mildew was poor and faulty application of the fungicide was suspected and checked by tracing. The spray was applied at 150 pounds per square inch (p.s.i.) with spray nozzles giving a coarse driving spray. Of both upper and under surfaces of the leaves, only 40 per cent had good cover, 35 per cent had poor or patchy covers and the remainder had no cover or only the merest traces.

Where it was present, the type of spray deposit differed on the upper and under surface of the leaves. Upper surfaces had a finer and more even deposit than the under surfaces, where the deposit consisted of much larger droplets. This is thought to be due to the larger droplets of spray impacting on the glass, so that only the finer ones reach the leaf.

Further tests were made using a small portable power machine and a variety of ceramic nozzles on an angled boom; a range of pressures were compared. In this way it was demonstrated to the grower that a good cover of about 95 per cent of the leaves could be obtained with a medium fan jet with a pressure of 45 p.s.i., thus reducing the spray consumption to approximately one quarter. Spraying was slower but much more efficient.

Spraying Potatoes

Tests were carried out on a field in Wiltshire, where the farmer used a boomed low-volume sprayer which sprayed only from overhead; the application rate was 20 g.p.a. The general cover obtained was very poor —good cover on the upper surfaces at the top of the plants, but only occasional patches below this level. There was little or no cover on the undersides, except in the two rows laid down by the passing of the tractor; in those rows there was excellent cover on the under surfaces of the leaves on one side of the plant, but not elsewhere, and upper surface cover was almost absent. The farmer was able to see for himself that his spraying was most inefficient and is now taking steps to acquire a better type of machine.

A test was also carried out on another type of low-volume machine where the overhead nozzles were supplemented by stalked nozzles running low between the rows; application was at 10 g.p.a. Again, cover was good on the upper surfaces at the tops of the plants and there was a considerable increase in the amount of upper surface cover lower down in the plants, but it was very patchy and variable. However, the result was a distinct advance on simple overhead spraying. It was clear that efficient spraying of a potato crop still remains something of a problem. A bar attachment to assist spray placement, such as has been used successfully on strawberries[3] may well improve results and it is hoped to test this in the future.

Spraying Soft Fruit

STRAWBERRIES

A grower specializing in strawberry runner production wished to know if his method of spraying was efficient, particularly as regards the undersides of leaves close to the ground. Spray was applied by means of two lances, each with three nozzles on a "broomhead" (i.e., a pipe at right angles at the end of the lance with the nozzles mounted 4 in. apart); the pressure was 400 p.s.i. and the amount applied was 200 g.p.a. Tracing tests brought out the interesting, and rather unexpected, information that the under surfaces of the leaves, including those close to the ground, were generally receiving a better deposit than the upper surfaces.

The reason was that the force of the spray, applied to each plant in turn, blew the leaves over and wetted the under surfaces thoroughly. As soon as the sprayer passed to the next plant the leaves dropped back into position and so received little spray, for by then the sprayer was directed to another plant.

The simple remedy for this was for the operator to spray ahead over the tops of the plants before dealing with the plant close to him; in this way the spray nozzles were not near enough to the plants to blow the leaves over and good upper cover was obtained. Close spraying was however an advantage in reaching the under surfaces. Very little spray was found within the young folded leaves and there was good cover on the outsides on one side only. Thus was demonstrated the importance of spraying from two directions—failure to do this being a common fault in row-crop spraying.

BLACK CURRANTS

Aphids present on his black currant crop caused a grower to doubt the efficiency of hand-spraying. A first test was made spraying in the same way as the grower. The pressure was 75 p.s.i., the spray coarse and the nozzle not angled. Spraying was a simple overhead and side application and cover proved to be very poor—mainly on upper surfaces on the outer parts of the bushes.

By tracing it was demonstrated that a finer nozzle, combined with an angled lance gave fairly good cover when the spray was applied upwards, downwards, and sideways. Large, dense bushes are very difficult to spray and, so far, this problem does not seem to have been solved.

A test carried out with a motorized knapsack air-blast machine on another holding gave results comparable to better hand-spraying, although the cover was far less efficient than on pyramid apple trees. The large amount of masking which takes place with blackcurrant foliage is due to the size, character and number of leaves and this is the great difficulty with this subject.

Top Fruit

Varied queries were also received from fruit growers regarding their spraying.

One grower of pyramid trees did his spraying with a hand lance, whilst sitting on a tractor-drawn trailer carrying pump and tank. Pressure was 200 p.s.i., the lance had a coarse two-nozzle broomhead and 150 g.p.a. of spray was applied; tractor speed was 2 m.p.h. He was not satisfied with scab control and suspected his application might be at fault. Tracing showed that very little spray was reaching the undersides of the leaves and that upper surface cover was patchy. Clearly the operator was too high in relation to the target. It was demonstrated with the tracer that if the spray nozzles were held low, spraying upwards into the trees, an excellent cover was obtained on the undersides and the rain-down of spray gave quite a good cover on the upper surfaces without any definite spraying to that end.

As a result, a fixed boom was devised, attached to the trailer and bearing three nozzles to spray upwards and two downwards; spraying was from one side, so that each row still had to be sprayed twice. A rough check on the output from the five finer nozzles showed that it would be about the same as with the previous hand spraying. Weather prevented a tracing test but the machine was tried out in the orchard and there seems little doubt that it will give a good account of itself; final adjustments and tests will be made in the spring.

A similar type of automatic sprayer, but spraying from both sides, was also tested. There were nine nozzles each side on an A-shaped boom; pressure was 75 p.s.i. and 350 g.p.a. were applied. The nozzles all sprayed in a horizontal direction and tracing showed very uneven cover on both upper and under surfaces in all parts of the trees. There was insufficient upwardly directed spray to give good under surface cover, or to provide a rain-down for upper surface cover. A temporary re-arrangement of the booms to achieve this at once made a marked improvement. The booms are now being properly adapted on those lines, with some downward spray at the top. Final tests and adjustments will be made in the spring.

EFFICIENCY OF HAND-SPRAYING

Hand-spraying from the ground has also been checked. Some of our tests have shown how very efficient it can be; but in others, the tracing not only showed that it could also be inefficient, but was a valuable aid in demonstrating spraying procedures which gave better results. In one instance, where 150 g.p.a. were being applied at 300 p.s.i., the cover was poor, particularly on the under surfaces low in the trees. Tracing demonstrated the great improvement through using angled nozzles, giving attention to more upward spraying and spraying inside the trees. Spray tracing is a valuable aid in training good sprayers; in this instance the spray operators had not realized that it was difficult to do good work with straight lances.

Akin to hand-spraying—in the sense that intelligent handling is necessary for good results—are the motorized knapsack air-blast machines. Tests were made with one of these on pyramid apple trees. The grower wished to know whether a small or large jet gave the best cover and whether his speed of walking down the rows was correct—or could he go faster. With the small jet the upper surface cover at the top of the trees was poor; the larger jet, with a larger droplet size, gave the necessary rain-down for such cover. It was also established that his speed of travel down the rows (about 1 m.p.h.) was correct—faster travel led to poorer cover.

TESTS ON AUTOMATIC HIGH-VOLUME SPRAYERS

Tests were carried out for growers on two other automatic high-volume sprayers on large trees. One applied 200 g.p.a. at a pressure of 400 p.s.i. and sprayed from both sides. There were six nozzles on each side, the outer ones spraying vertically and the inner ones a little lower than those in the middle. This would be expected to give a good upward spray and provide ample rain-down. Tracing showed this to be so, but revealed a weakness in cover in the lower parts of the trees. The nozzles were all the same. Substitution of the three lower nozzles on each side by finer nozzles at once remedied this defect and cover was then, for all practical purposes, complete.

The other automatic sprayer tested was applying 250 g.p.a. at a little less pressure (300 p.s.i.). Again there were twelve nozzles, but all these were mounted on one obliquely-mounted boom and spraying was from one side only. After spraying both sides of the trees it might be expected that the cover would be equal to that of the other machine, but in fact it was inferior, particularly as regards upper surface cover. The fault clearly lay in the angle at which the boom was carried. The spray was being directed sideways, rather than upwards, as with the first sprayer, and rain-down was poor. It is likely that changes in nozzle layout will be made and tested until good results are obtained.

AIR-BLAST SPRAYERS

A number of tracing tests were made with air-blast sprayers to provide information required by growers. In two cases growers were in some doubt as to the efficiency of cover provided by low-volume spraying, of the order of 30 g.p.a. The tests showed that such covers were very uneven and the growers have decided to increase the rate to 100 g.p.a., at least for the more important spray applications. On one holding it was found that a 30 g.p.a. application gave a much better cover on pears than on apples; the stiffer and smoother foliage of the pear was evidently the reason. A popular small air-blast machine was also checked by tracers on several holdings, mainly so that growers might know if their setting and use of the machines was giving good results. Tracing

enabled small changes in adjustment to be made and the improvements to be demonstrated.

An air-blast sprayer of a rather different type was also tested. The cover was very patchy, poor low in the trees with poor upper surface cover at the top. The machine had four separate spray nozzles and the total angle of the spray arc was only about 70 degrees. Increasing this arc by altering the position of the nozzles resulted in wider gaps and so increased the areas where spray concentration was low. Four extra nozzles, provided for use when spraying from both sides, were then fitted, but all on one side and evenly spaced, giving a spray arc of over 100 degrees. The top nozzle pointed vertically and the bottom nozzle a little below the horizontal.

Increased cover was then obtained, but unfortunately a rather windy day had been chosen for the tests and it was obvious that much of the spray was being driven down-wind and so affected the rain-down on the row being sprayed. However, samples of shoots from the upper parts of trees in the rows down-wind were examined and it was found that good covers on the upper surfaces were to be found in the next row 12 ft down-wind; there were some useful covers 24 and 36 ft down-wind and some as far away as 48 ft. There was much one-sided cover on the windward sides of trees right across and as far as 68 ft away. Given reasonably calm weather it was clear that excellent covers would be obtained. The observations demonstrated the importance of cover build-up over a block of sprayed trees.

TESTS WITH NURSERY MATERIAL

An interesting series of tests were carried out with a small air-blast sprayer on a large nursery, where bush apples and pears, standard cherries and roses were particular features. Much of the nursery material was in blocks of up to a dozen rows and so extended 30 ft, or more, across. The grower wished to know if the machine could tackle such a spraying problem. It was found that blocks of up to six rows across could be dealt with satisfactorily. With larger blocks, cover was poor in the middle rows and weak on the insides of the outer rows, because spraying was done from both sides of the blocks. It was also found that mixed blocks of tall cherries and low apples were unsatisfactory; the tops of the cherries suffered if the apples had good cover. The point was made that material differing greatly in height was best not planted together in the same block.

While there was some doubt whether such a low crop as roses could be sprayed satisfactorily, surprisingly good results were obtained on a block containing eleven rows. The middle rows had weak cover, but it was clear that six-row blocks would be satisfactory. The grower decided that the machine would suit him well and that he would gradually re-organize his nursery on a 6-row block system, with long rows and tractor alleys in between.

County Staffs acquiring Apparatus

It is hoped that the above account of field tests will have shown how useful such tests can be in the course of advisory work. Those growers and farmers who have been concerned have all expressed themselves as being very pleased with the help thus provided. It is certain that increasing requests will come in for help of this kind, and more than can be handled by a regional specialist. For this reason some of the counties in this Region have already provided themselves with the necessary apparatus and will be able to use them for advisory purposes next season; other counties are likely to follow suit.

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